MILLI™ 5

PRODUCT DATA SHEET

Silver Spring NETWORKS

KEY BENEFITS

- Integrates with Silver Spring Networks mesh networking technology
- Long range
- Low power (+23dBm output power) and small form factor
- Support for IPv6, RFC 7252 Constrained Application Protocol (CoAP), and Wi-SUN 802.15.4g radio
- Security with standard cryptographic algorithms and PKI-based implementation
- Bi-directional communications
- OTA firmware updates

The Silver Spring Networks Milli 5 is a wireless communications module optimized for battery-powered devices enabling the Internet of Important Things™. The Milli 5 leverages Silver Spring Networks' proven, self-forming, self-healing networking capabilities to bring connectivity to a new class of IoT devices. The small form factor and power-optimized design brings secure, reliable two-way integrated IPv6 connectivity to critical infrastructure.

Silver Spring Networks Technology

Silver Spring Networks provides autonomous wireless communication to geographically distributed devices, utilizing on-board firmware to securely communicate and interoperate with compatible wireless nodes to form a wireless mesh network. Silver Spring employs frequency hopping techniques to hop through frequency channels in unlicensed spectrum available worldwide. Each node "hops" in a pseudo-random hopping sequence, meaning each node synchronizes with other nodes in order to communicate on the network. Silver Spring utilizes time-based synchronization based upon a common time propagated through the network as a resource.

Upon boot-up, Silver Spring devices enter acquisition mode, where they scan the available frequencies for discovery beacons. The discovery beacon contains the information necessary to synchronize their frequency-hopping. A host is any device to which the communications module is connected. A host application is any application that runs on that host.

Silver Spring Network's IPv6 mesh is designed to mitigate unnecessary traffic as much as possible to reduce the probability for interference, excessive noise floor, and other deleterious RF effects that typically occur when unnecessarily chatty protocols are used—that is, those with excessive keep-alive, polling, and other messages being broadcast continually. Each node is capable of dynamically identifying alternate routes

SPECIFICATIONS

Radio and Networking Capabilities

- Operates in 870-875.6 and 902-928 MHz
- RF output power: 200 mW (+23 dBm)
- ARM Cortex-M3 32bit-processing for low power
- 50 kbps data rate

Security Assurance

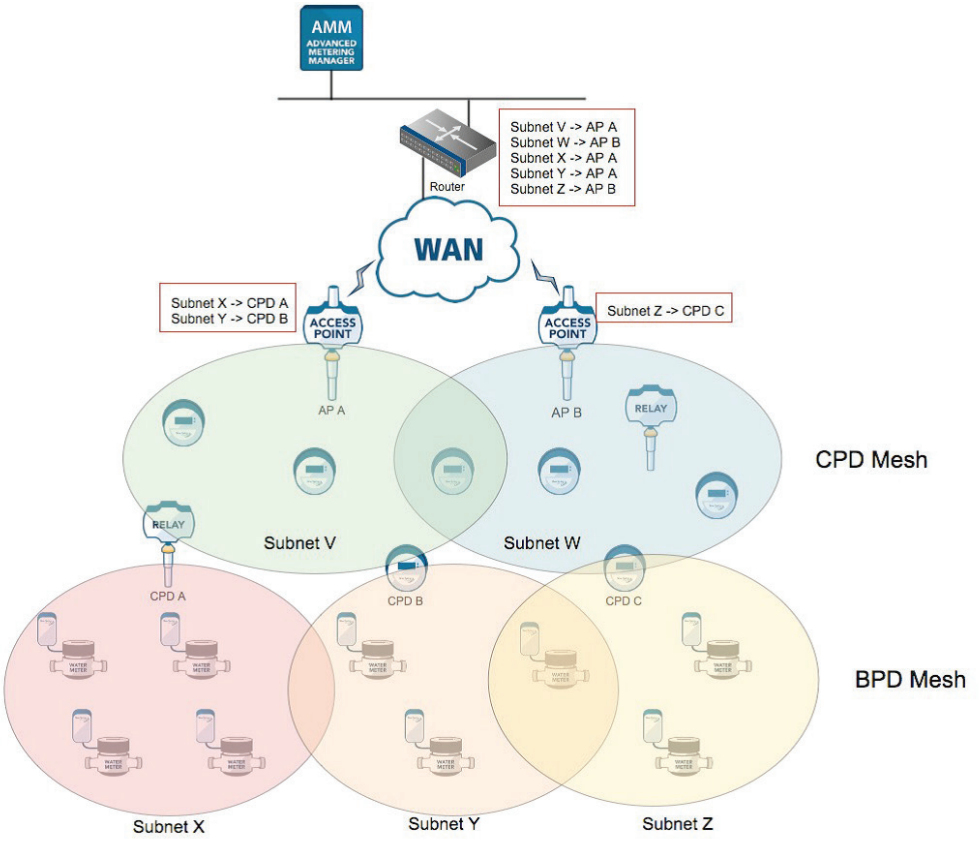
- Certificate-based app-layer protocol authentication (ECDSA)
- Data Confidentiality (AES128)
- Firmware validation (ECDSA)
- Link Layer (AES128)

Hardware Interfaces Available

- F/W currently supports CoAP over UART

Please contact Silver Spring Networks about the roadmap for support of other interfaces or if your application requires a different interface.

if required due to outages, link failures or other conditions. This leads to an extremely resilient network topology compared to other star topologies.



The (logical) network topology of a battery mesh. The nodes in the diagram represent logical positions (not physical locations) in the battery mesh routing tree.

How Milli 5 Battery Meshing Works

In a battery-powered device, Milli 5 operates off the host's power supply. To conserve power, Milli 5 spends most of its time sleeping. (Nodes sleep when not otherwise occupied with operations.) Milli 5 sleeps at about 1.4µA or ~0.3 Joules/day. During installation, battery-powered devices (BPDs) perform an aggressive discovery of other BPDs or constantly powered devices (CPDs). Thereafter, BPD nodes wake up periodically and listen in a receive window. The energy required for receiving is approximately 3mJ/second. Upon power-up, Milli 5 listens periodically for discovery packets from CPD/BPD. These are used to establish time synchronization and establish the node on the network.

Physical Specifications

Parameter	Value
Size	30x25x2.5mm
Weight	5g (approximately)
Package Type	LGA – 72 pins
Material	PCB Board

Electrical Specifications

This section contains electrical specifications for Milli 5.
Note: All specifications are subject to change without notice.

Absolute Maximum Ratings: Under no circumstances must the absolute maximum ratings be violated. Stress exceeding one or more of the limiting values may cause permanent damage to the device.

Parameter	Conditions	Value	Unit
Supply voltage	All supply pins must have the same voltage	-0.3 to 3.6	V
Voltage on any digital pin	-	-0.3 to VDD+0.3, max 3.6	V
Input RF level	-	+10	dBm
VSWR limit	At antenna port	10:1	
Storage temperature range	-	-40 to +120	°C
Reflow soldering temperature	According to IPC/JEDEC J-STD-020	260	°C
ESD	• Human Body Model • Charged Device Model (RF pins) • Charged Device Model (non-RF pins)	250 250 250	V

Recommended Operating Conditions

Parameter	Conditions	Min	Max	Unit
Ambient temperature range	0-95% RH	-40	85	°C
Supply voltage	-	3.1	3.6	V
Input voltage	Do not exceed the absolute maximum voltage	-0.3	VDD +0.3	V
Ripple	-	-	10	mV
Transient	-	-	20	mV

Power Consumption

Parameter	Typ	Max	Unit	Conditions
Sleep/Power-down	~ 10 µA target goal (RTC and SRAM retention)	-	µA	32 kHz clock running, MCU register retention, full RAM retention
RF channel sense	~2	-	mA	-
Power Consumption Radio RX	7	-	mA	RX sniff mode, searching for packet
Power Consumption Radio TX	172	200	mA	-

Receive Parameters

Parameter	Min	Typ	Max	Units	Conditions (870 - 875.6 and 902 - 928 Mhz)
Sensitivity	-	-104	-	dBm	10% PER and 50 kbps
Blocking	40	50	-	dB	200 & 400kHz channels (802.15.4g)
Spurious Emissions	-	-55	-	dBm	< 1 GHz
Image Rejection	-	50	-	dB	FW controlled image rejection optimized

Transmit Parameters

Parameter	Min	TYP	Max	Conditions
Output power highest setting	20	22	23	dBm
Output power lowest setting	-3	0	5	dBm

DEVELOPER PORTAL

Milli-based Arduino Shield kits are available to develop IoT applications. The kits can be purchased at Silver Spring's developer portal:

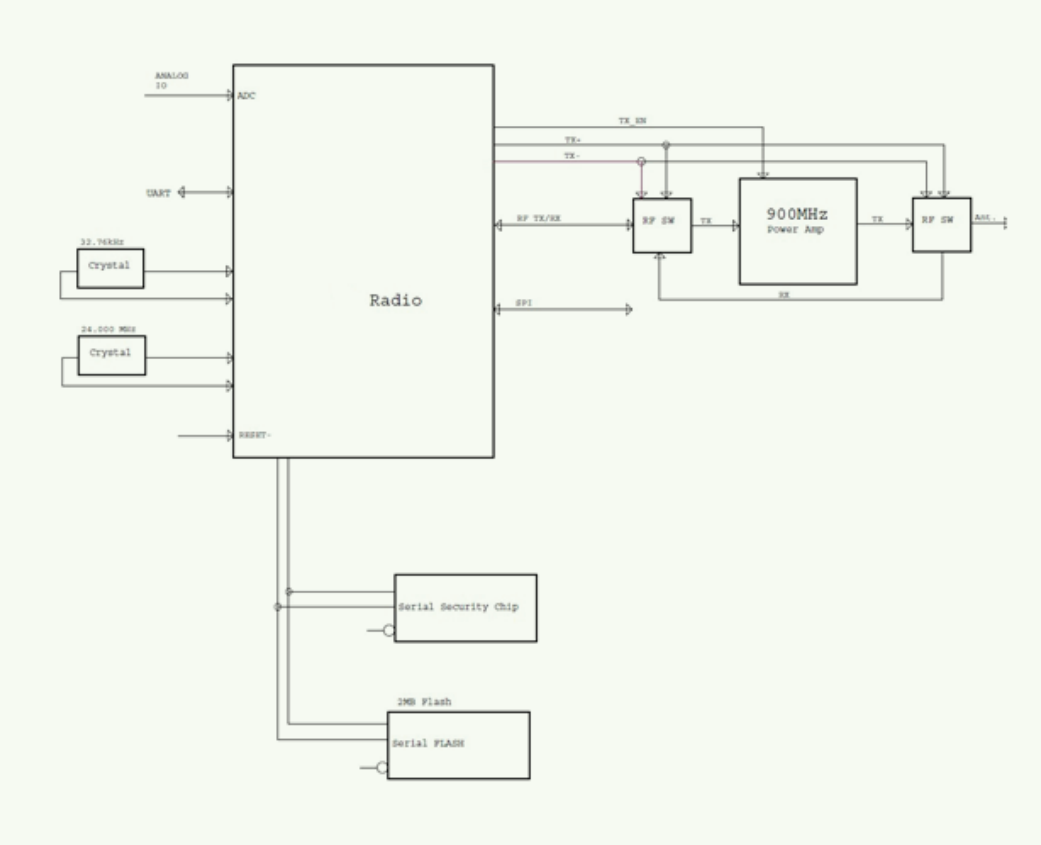
developer.ssni.com

to start POC (Proof Of Concept) projects. This developer portal has the required documentation to get started with the kit, download and recreate reference applications, establish end-to-end connectivity from the sensors to the back office data platform, interact with other users through forums, and create support tickets to get help.

Signal Interface

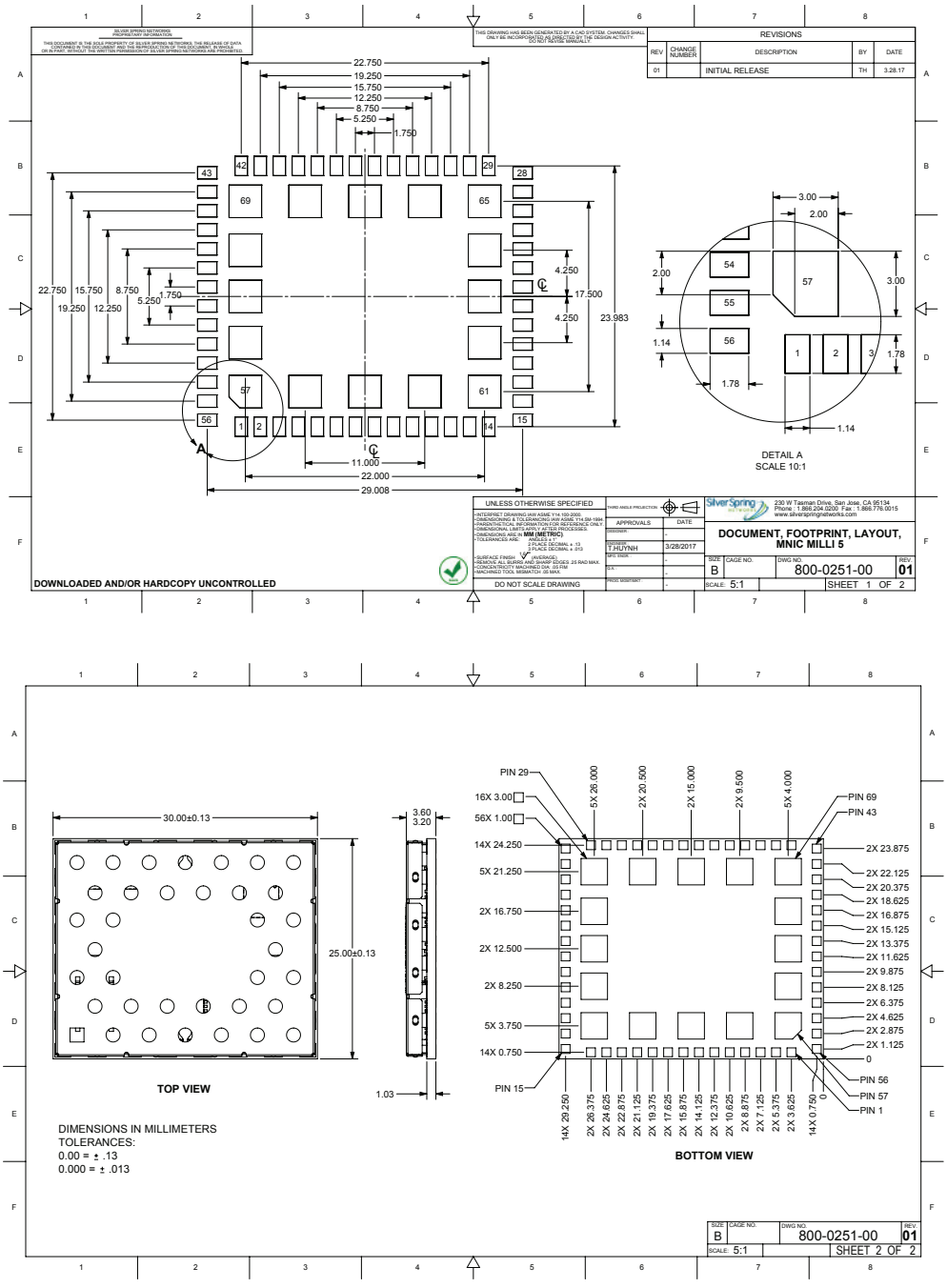
The Silver Spring Networks Milli 5 is an SMT reflow Land Grid Array (LGA) module with I/O and power connections at the bottom.

Milli 5 Block Diagram



Mechanical Specifications

Note: The ground pads on the module's bottom side must be connected to electrical and thermal performance.



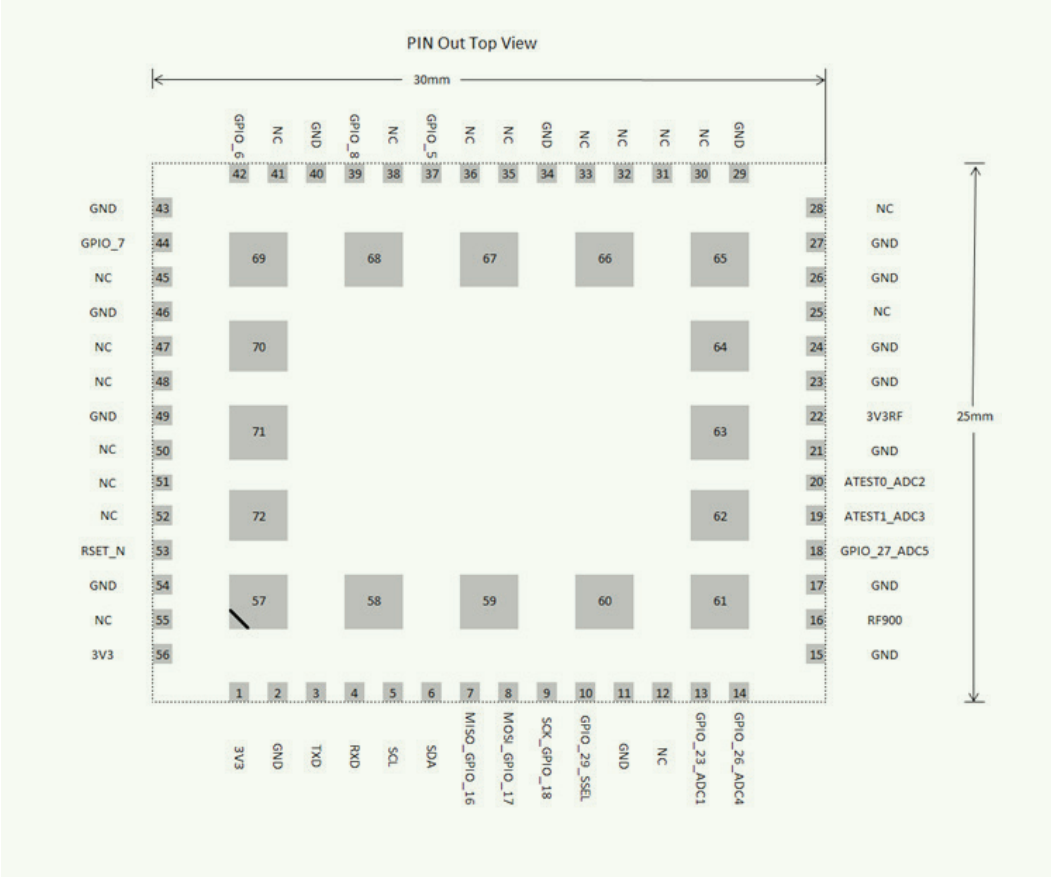
Mechanical dimensions and land pattern

Pin 1 Identification

On the top side, Milli 5 has a 2D barcode to identify MAC address, part number, and other key product data that is needed. The pinhole also represents the Pin 1 corner on the Milli 5 assembly. Note: The horizontal flips bottom pins 180°.

Pin Assignments and Signal Description

The Milli 5 module provides connecting pads to integrate the module into external applications. Figure below shows the pin assignments and Table 1 lists the pins and signal descriptions. Note that pin assignments are preliminary and might change at a later date.



Pin assignments

Note: Pins marked "NC" (no connect) can be soldered but must be left open, and not be connected to an external application. It is highly recommended that all pads be soldered.

Pins and signal descriptions

Pin Number	Signal Name	Input/Output	Description
1	3V3	Power	3.1V - 3.6V main module supply
2	GND	Power	Ground
3	TXD	Output	UART interface, RXD/TXD (Serial Interface) communications (up to 115,200 bps, 8-N-1)
4	RXD	Input	UART interface, RXD/TXD (Serial Interface communications (up to 115,200 bps, 8-N-1)
5	SCL	Output	NC
6	SDA	I/O	NC
7	MISO-GPIO_16	I/O	NC
8	MOSI_GPIO_17	I/O	NC
9	SCK_GPIO_18	I/O	NC
10	GPIO_29_SSEL	I/O	NC
11	NC (Test RSV)	I/O	NC
12	NC (Test RSV)	I/O	NC
13	GPIO_23_ADC1	I/O	NC
14	GPIO_26_ADC4	I/O	Add 10K or bigger pullup resistor and connect to 3.3V
15	GND	Power	Ground
16	RF900	I/O	RF I/O port, 50 ohm nominal
17	GND	Power	Ground
18	GPIO_27_ADC5	I/O	NC
19	ATEST1_ADC3	I/O	NC
20	ATEST0_ADC2	I/O	NC
21	GND	Power	Ground
22	3V3RF	Input	NC
23	GND	Power	Ground
24	GND	Power	Ground
25	NC	N/A	NC
26	GND	Power	Ground
27	GND	Power	Ground
28	NC	N/A	NC
29	GND	Power	Ground
30	NC	N/A	NC
31	NC	N/A	NC
32	NC	N/A	NC

Pin Number	Signal Name	Input/Output	Description
33	NC	N/A	NC
34	GND	Power	Ground
35	NC	N/A	NC
36	NC	N/A	NC
37	GPIO_5	I/O	Interrupt pin – Pin to wake up host processor from Milli 5
38	NC	N/A	NC
39	GPIO_8	Output	Is an open collector pin that Milli 5 would pull low to affect the host device to reset.
40	GND	Power	Ground
41	NC	N/A	NC
42	GPIO_6	I/O	NC
43	GND	Power	Ground
44	GPIO_7	Input	Interrupt pin - wakes up Milli 5 so host processor can send data
45	NC	N/A	NC
46	GND	Power	Ground
47	NC	N/A	NC
48	NC	N/A	NC
49	GND	Power	Ground
50	NC	N/A	NC
51	NC	N/A	NC
52	NC	N/A	NC
53	RSET_N	Input	Milli 5 module master reset. Active low input. When asserted, all outputs will be made high impedance
54	GND	Power	Ground
55	NC	N/A	NC
56	3V3	Power	3.1V – 3.6V main module supply
57-72	GND	Power	Ground

* Pins 3-16 are bi-directional, inputs are pull up/pull down, and outputs are configurable as push-pull or open drain. Drive capacity varies with pin.

50 ohm PCB Design Guidelines

Antenna design and RF layout are critical in a wireless system that transmits and receives electromagnetic radiation in free space. The Milli 5 module does not include an antenna connector. The antenna (or unique antenna connector) must be connected to Milli 5 via a transmission line implemented on the host PCB.

SSN recommends the use of a co-planer Waveguide to minimize space and board real estate. The PCB trace should be kept as short as possible to minimize path loss.

IPC 6011 and IPC 6012 Class 2 or better PCB manufacturing practices must be followed to ensure repeatable results.

The transmission line trace will be bounded on both sides by a ground reference plane. For EMI considerations this ground plane should be extended and connected to other ground layers, one of which is on the opposite side of the PCB. The opposite side ground plane shall be contiguous under the trace and shall extend beyond the trace. These ground planes should be stitched together using vias spaced 40-50 mils (2 mm) apart. Avoid breaking up these ground planes by routing traces through them.

Avoid routing any other signal traces, especially high speed digital signals, near the transmission line. Locate the transmission line trace away from power supply lines and power supply regulatory circuitry.

Key design parameters

The antenna trace must have a characteristic impedance of 50 Ω ± 5%. The recommended dimensions and the Gerber layout for the antenna trace are provided on the following pages. To calculate the key parameters requires calculating transmission line parameters. Although there are many transmission line and trace impedance calculators found on-line, they are not as thorough as specialized tools, and in simplifying the calculations, may omit critical variables.

Silver Spring recommends the use of AppCAD Design Assistant. This software is available as a free download from Avago Technologies:

http://www.avagotech.com/appcad

Additional support information on AppCAD can be found here:

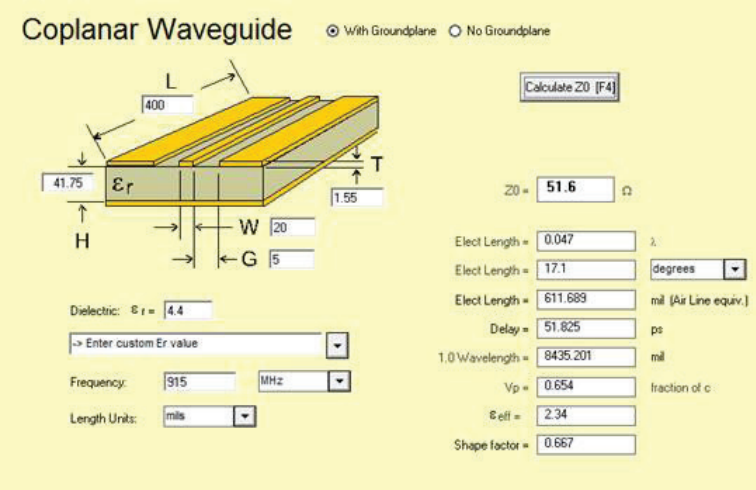
http://www.hp.woodshot.com/

This reference design uses 1 oz copper. The base PCB material is ITEQ IT-180A. Data sheet is available here:

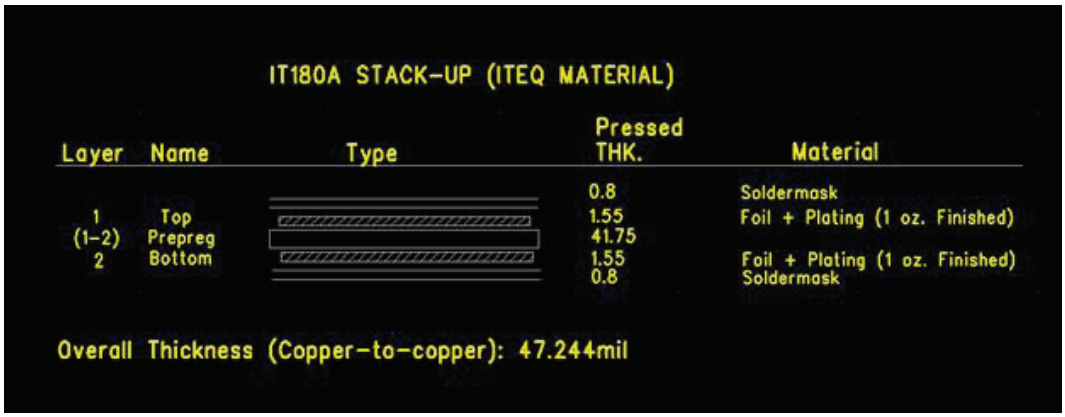
http://www.prototron.com/documents/materials/IT-180A.pdf

which has an ε_r specified as 4.4.

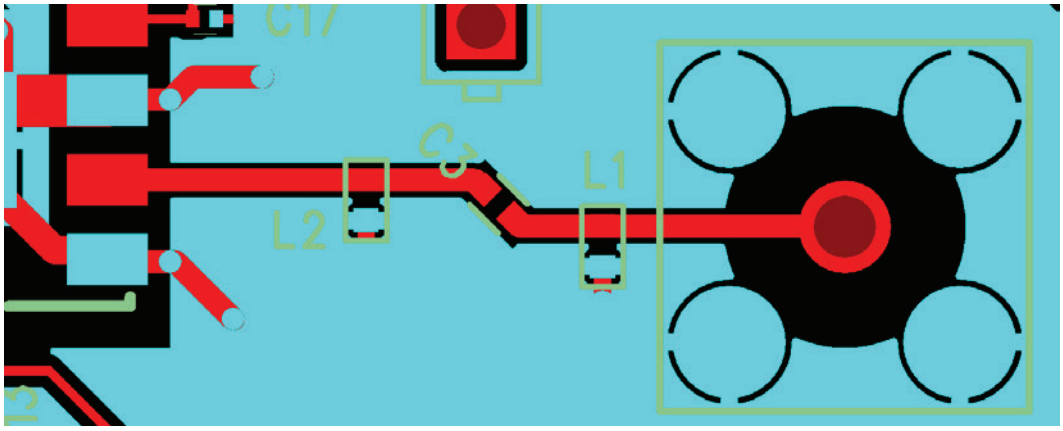
PCB Design Guidelines; Silver Spring Networks Milli 5 Development Board Layout



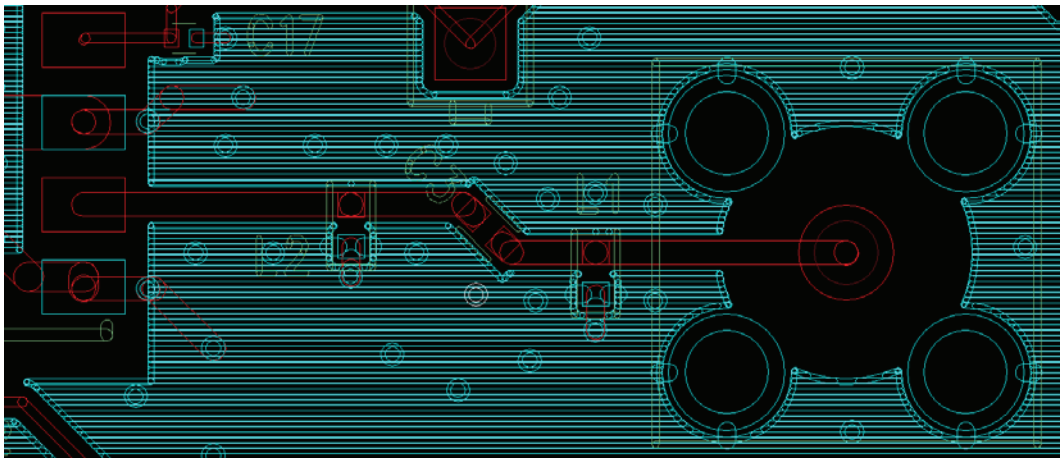
Antenna trace design parameters



PCB Stackup



Coplanar Waveguide with Full Ground Pour



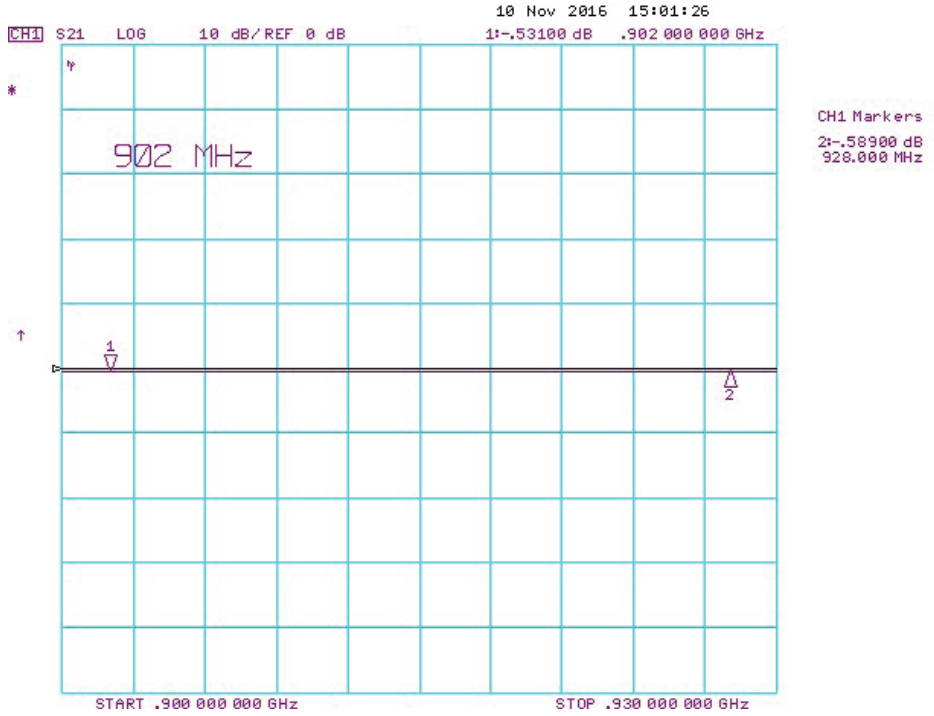
Coplanar Waveguide with ground outline showing vias 50 mils spaced

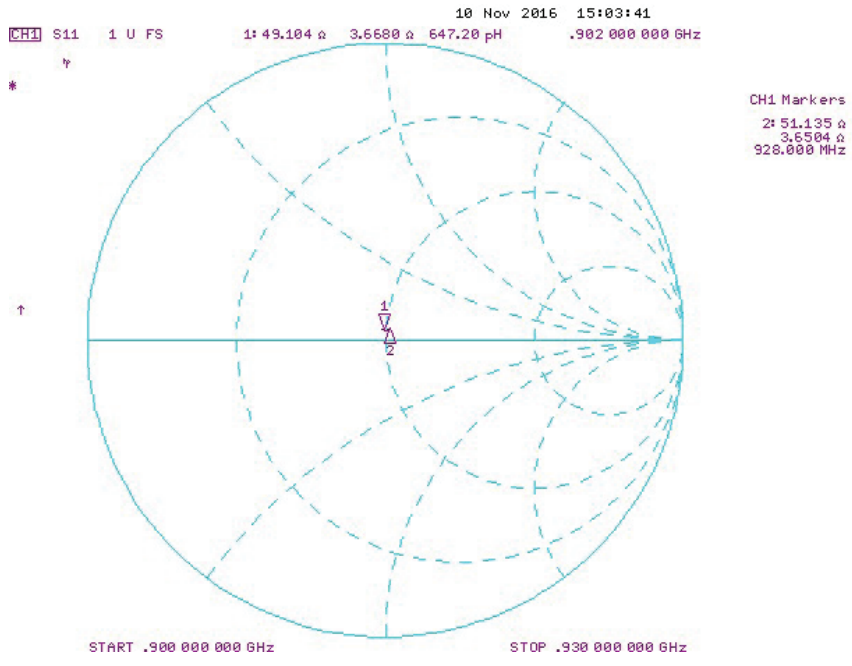
Transmission Line Measurements

For design verification, use of an S-Parameter Network Analyzer, such as Agilent 8719S may be used to characterize the losses of the transmission line. Solder a calibrated coaxial cable to pin 16 (RF900, RF I/O port) pin on the PCB to make the following measurements.

Path loss measurements, S12.

Line input impedance (Smith chart format) once the line has been terminated with a 50 ohm load is shown below.





FCC AND INDUSTRY CANADA GOVERNMENT GUIDELINES

Silver Spring Networks Milli 5
FCC ID: OWS-MIL51
IC: 5975A-MIL51

Modifications

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Part 15 Certification Notice

This device complies with Part 15 of the FCC Rules and Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

The antenna of this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

The device should be installed so that people will not come within 20 cm (8 in.) of the antenna.

Information to User for Class B digital device

This equipment has been tested and found to comply with Part 15 of the FCC Rules. This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception (which can be determined by turning the equipment off and on), the user is encouraged to try to correct the interference by one or more of the following measures:

» Reorient or relocate the receiving antenna.

» Increase the separation between the equipment and receiver.

» Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

» Consult the dealer or an experienced radio/TV technician for help.

Exigences d'Industrie Canada

La carte d'interface réseau (NIC) Silver Spring Network Relay Point (NRP) DOIT être installée par un technicien ayant reçu une formation adéquate. Une installation incorrecte peut annuler l'autorisation de l'utilisateur à se servir de l'équipement. Le présent appareil

est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

(1) l'appareil ne doit pas produire de brouillage, et.

(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

L'antenne de cet émetteur ne doit pas se trouver à proximité de ou fonctionner en association avec une autre antenne ou un autre émetteur.

L'appareil doit être installé de telle sorte que les gens ne viendront pas au sein de 29 cm (11.4 in.) de l'antenne.

Les changements ou modifications apportés sans l'approbation expresse de l'autorité responsable de la conformité pourront entraîner l'annulation de l'autorisation d'utilisation de cet équipement.

Labeling Requirements for Host Device

The following is an extract from FCC PART 15 UNLICENSED MODULAR TRANSMITTER APPROVAL, DA 00-1407, Released: June 26, 2000, Section 6 describing labeling requirements for devices containing a modular transmitter.

Section 6. The modular transmitter must be labeled with its own FCC ID number, and, if the FCC ID is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. This exterior label can use wording such as the following: "Contains Transmitter Module FCC ID: XYZMODEL1" or "Contains FCC ID: XYZMODEL1." Any similar wording that expresses the same meaning may be used. The Grantee may either provide such a label, an example of which must be included in the application for equipment authorization, or, must provide adequate instructions along with the module which explain this requirement.

In the latter case, a copy of these instructions must be included in the application for equipment authorization.

The following is an extract from RSS-GEN, General Requirements and Information for the Certification of Radio Apparatus, Section 3.2.1, describing labeling requirements for a host device integrating a radio module.

The host device shall be properly labelled to identify the modules within the host device.

The Industry Canada certification label of a module shall be clearly visible at all times when installed in the host device, otherwise the host device must be labelled to display the Industry Canada certification number of the module, preceded by the words "Contains transmitter module", or the word "Contains", or similar wording expressing the same meaning, as follows:

> Contains transmitter module IC: XXXXXX-YYYYYYYYYY where XXXXXX-YYYYYYYYYY is the module's certification number.

L'extrait suivant provient du Cahier des charges sur les normes radioélectriques (CNR); exigences générales et information relatives à la certification des appareils radio, section 3.2.1, et décrit les exigences en matière d'étiquetage pour un dispositif hôte intégrant un module radio. Le dispositif hôte doit être correctement étiqueté afin d'identifier les modules qu'il comprend.

L'étiquette de certification Industrie Canada d'un module doit toujours être bien visible lors de l'installation sur un dispositif hôte. Dans le cas contraire, le dispositif hôte doit être étiqueté de façon à afficher le numéro de certification Industrie Canada du module, précédé de l'expression « Contains transmitter module » ou du mot « Contains », ou d'une formulation similaire ayant la même signification. Par exemple :

> Contains transmitter module IC : XXXXXX-YYYYYYYYYY où XXXXXX-YYYYYYYYYY représente le numéro de certification du module.

The applicant for equipment certification of the module shall provide with each unit of the module either a label such as described above, or an explanation and instructions to the user as to the host device labelling requirements.

External Antenna Integration (RSS-GEN)

This radio transmitter 5975A-MIL51 has been approved by Industry Canada to operate with the antenna types listed in Table 2 with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet émetteur radio 5975A-MIL51 a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le tableau 2 ci-dessous avec le gain maximal admissible et l'impédance d'antenne requise pour chaque type d'antenne indiqué. Les types d'antennes ne figurant pas dans cette liste, ayant un gain supérieur au gain maximum.

External Antenna

Antenna	Antenna Type	900 MHz Gain (dBi)	Antenna Impedance
J-Pole, SSN 201-000006	Omni Directional	3	50
Linx, ANT-916-CW-RH-SMA-ND	Stub	-1.3	50
Pulse W1900	Stub	1	50

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its

gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Milli 5 Radio Certifications

Silver Spring Networks Milli 5 is integrated into application specific hosts which provide power regulation, buffered data inputs, and 50 ohm transmission line to antenna or external antenna connector. The following table describes the hosts that support Milli 5 FCC/IC Certification.

SSN P/N	Description	Antenna
174-0768-00	Hardware Development Kit (HDK)	External SMA
170-0818-00	Logistics NIC (LNIC)	On-board – SSNI 420-0319-00
170-0845-00	Milli Arduino Shield Board	External SMA

OEM Certifications

Silver Spring Networks Milli 5 is FCC/IC Certified as Limited Modular Approval (LMA). LMA may be granted to a device which cannot meet all the requirements of a Single Modular Transmitter and if compliance can be demonstrated under the operating conditions in which the device will be used. OEMs have the following options for FCC/IC Certification using an LMA:

Option 1: Use current FCC/IC Grant, without need of an additional Certification by following these rules:

» Design to the strict guidelines for layout as described in 50 ohm PCB Design Guidelines,

» Use an external antenna of same type as tested (J-Pole Omni-Directional) with equal or less gain,

» Deliver power regulation to Milli 5 as described in Recommended Operating Conditions,"

» Deliver buffered modulation/data inputs to Milli 5

» Label the host device with, "Contains FCC ID: OWS-MIL51" and "Contains IC: 5975A-MIL51."

Option 2: If all rules from Option 1 are used, but a different type of antenna is required for the application, request a Change in ID application to reuse data from the current FCC/IC Grant, then apply for a Class 2 Permissive Change to add the antenna. The integration would require some additional conformity against CFR 47 Parts 15.203, 15.209, and RF exposure to add antenna to the Certification. Contact Silver Spring Networks for authorization to apply for a Class II Permissive Change.

Option 3: Integration will need to pursue own full FCC Certification if design does not follow strict guidelines for layout. OEM may choose to obtain own FCC Certification even if guidelines are followed.

Collocation: If other wireless technologies are operational at the same time, then certification testing may be required for each technology, including evaluations of simultaneous transmissions from independent transmitters.

ABOUT SILVER SPRING NETWORKS

Silver Spring Networks enables the Internet of Important Things™ by reliably and securely connecting things that matter. Cities, utilities, and companies on five continents use the company's cost-effective, high-performance IoT network and data platform to operate more efficiently, get greener, and enable innovative services that can improve the lives of millions of people. With more than 25.5 million devices delivered, Silver Spring provides a proven standards-based platform safeguarded with military grade security. Silver Spring Networks' customers include Baltimore Gas & Electric, CitiPower & Powercor, ComEd, Consolidated Edison, CPS Energy, Florida Power & Light, Pacific Gas & Electric, Pepco Holdings, and Singapore Power. Silver Spring has also deployed networks in Smart Cities including Copenhagen, Glasgow, Paris, Providence, and Stockholm. To learn more, visit www.ssni.com.

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